

CIGRE TF 15.01.09

"Dielectric response methods for diagnostics of power transformers"

CONCLUSIONS AND GUIDELINES (September 2001)

Members:

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Background for TF activities

The dryness and ageing state of the oil-paper insulation is a key factor in both the short and long term reliability of a power transformer since moisture has deleterious effects on dielectric integrity and insulation ageing rates. Unfortunately, there is no universally accepted method of determining the dryness of the pressboard as used within such insulation systems. Because moisture partitions unequally between the oil and the pressboard, the vast majority residing within the solid insulation, with the concentration in the oil being highly temperature dependent, the measurement of moisture in oil is not a reliable indicator of dryness, particularly for lightly loaded transformers. Although in principle moisture can also be extracted from pressboard samples and measured, this approach is hampered by the impossibility of obtaining samples from critical locations, and the significant variation in results that can arise from different practices regarding sample storage and preparation.

Most recent attention has been directed to methods of determining moisture content and ageing of the pressboard indirectly by measuring the effects of moisture on electrical properties. Rather than the traditional measurement of power frequency loss angle, recent attention has focussed on measuring various dielectric response parameters, which characterise some known polarisation phenomena. The three foremost techniques are:

- recovery or return voltage measurements (RVM),
- dielectric spectroscopy in time domain, i.e. measurements of polarisation and depolarisation currents (PDC),
- dielectric spectroscopy in frequency domain, i.e. measurements of electric capacitance C and loss factor $\tan \delta$ in dependency of frequency (FDS).

Until recently the RVM technique has by far been the most popular method. However, there has been much controversy surrounding the technique, which has been criticised on various grounds:

- moisture determinations, as derived by the evaluation method used, are often much higher than obtained by other methods,
- the recommended interpretation scheme is too simplistic,
- the technique does not take into account dependencies on geometry and oil properties.

On the other hand there has not been so much knowledge on how to interpret the results of the PDC and FDS measurements. The work in this direction has been in progress for a few recent years. Also the possibilities of modelling the transformer insulation properties as well as of comparing the data obtained by means of the three techniques is still under intensive development.

As a result CIGRE Working Group 12.18.TF 4 reviewed the opinions of users of polarisation techniques and concluded that although such techniques showed promise, more work was required to validate the techniques and improve the interpretation of results. Subsequently Task Force 15.01.09 was set up in 1999 to compare the three main techniques. Initial work has concentrated on measurements using all the techniques on an insulation model designed specifically to verify the influence of insulation geometry, on dielectric responses, and has

included comparisons with a mathematical model of polarisation behaviour. Furthermore, the influences of the thermodynamic equilibrium between paper and oil as well as the oil conductivity were tested on this model. In parallel, number of activities were undertaken in UK, Switzerland and Sweden, which included performing measurements with the above named techniques on selected power transformers in field conditions.

In September 2001 the work of TF 15.01.09 was summarised and conclusions regarding the state of the knowledge on the applicability of the techniques were prepared and are presented below. Final report of the group is to be published shortly in ELECTRA (short version) and as a special brochure (full version).

This report presents first a general background for understanding the polarisation phenomena in electrical insulation. The relations derived are essential for understanding and processing the data obtained from dielectric measurements. It is followed by a description of the theoretical principles for the polarisation measurements and, in particular, for the three techniques used. Special emphasis is put to the description on how to interpret and model the results obtained. Then the model experiments are described and analysed. Finally, the study cases from UK and Sweden are presented. List of relevant references and other related literature is provided at the end of the report as well.

Conclusions

The results of work of TF 15.01.09 presented in this report confirm that the dielectric response measurements provide valuable information on the state of oil-paper insulation in power transformers, in particular the moisture content. All the dielectric response methods compared (RVM, FDS, PDC) reflect the same fundamental polarisation and conduction phenomena in transformer insulation, the special feature of which is a combination of oil gaps and solid insulation.

The dielectric measurements described here confirm that due to the influence of oil gaps, the condition of the oil, specifically its conductivity, has a significant impact on dielectric response, and this must be taken into account when attempting to estimate moisture contents in the solid insulation from the results of all three methods.

Regarding the influence of geometry, it has an influence on the response but not as significant as the effect of the oil conductivity. For the tested sizes of oil gaps, which are typical for the transformer insulation, it is first of all the existence of the gaps rather than their detail dimensions which has the main impact on the results of the measurements.

For the RVM technique, the old interpretation based only on simple relationship between the dominant time constant of the polarisation spectrum and the water content in cellulose is not correct. An improved interpretation requires taking into account the complete measured curve. An alternative qualitative interpretation has been proposed which resolves some previous anomalous conclusions.

Mathematical modelling provides a link between the measured responses of the applied three methods and shows how responses are affected by oil conductivity (resistivity), moisture content and object geometry. Knowledge of the dielectric properties of insulation components is needed for this purpose. Such modelling is recommended today for interpretation of the results of all methods.

Before operational decisions concerning life management of transformers can be made with confidence from the indications of the dielectric response techniques, further validation is required. There is a particular need to verify the estimates of water content determined by the dielectric response techniques by comparison with basic chemical measurements. The influences of different types of pressboard/paper and ageing products (beyond the effects of oil conductivity and moisture) on dielectric response have yet to be determined conclusively.

Since all three methods use different measurements, they could in principle and appear to have in practice, their own strengths and weaknesses. These need to be assessed further before any one can be recommended over the others.